Updated spatial analysis of BSAI blackspotted/rougheye rockfish catch in fishery and trawl survey tows

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Executive summary

In 2013, a report was presented to the BSAI Plan Team that identified 1 genetic and 6 non-genetic attributes for BSAI blackspotted rockfish (Spencer 2013). The 6 non-genetic attributes pertained to spatial analyses of catch and survey data, which the BSAI Plan Team found “compelling” and formed the basis for their “strong concern” over the harvest rates and abundance in the western Aleutian Islands. The BSAI Plan team requested an update of the 7 attributes for September 2014. This report provides updates for those attributes which have updated data since 2013, which include genetic data and catch data; attributes regarding historical catch and survey abundance, or those which rely solely on survey data are not repeated here but will be updated when the 2014 Aleutian Islands survey results become available.

New genetic samples were collected in the 2010 and 2012 Aleutian Islands trawl survey, and substantially increased the sample size and number of loci examined from the original blackspotted rockfish genetic study in 2010 (Spencer and Rooper, 2010). The previous conclusion of an isolation by distance relationship is not supported with the updated dataset. A sensitivity analysis indicates that the both the change in sample size and number of loci examined contribute to the difference between the two studies, with additional loci contributing more to that difference.

The area-specific catch rates and spatial distribution of harvest, with the updated catch data, show largely the same pattern as observed in Spencer (2013), and do not provide evidence that would alter the non-genetic attributes identified by Spencer (2013). The updated catch data indicate that the 2013 harvest of blackspotted rockfish in the western AI resulted in the highest exploitation rate since 2004.

A defining feature of the report of the Stock Structure Working Group (Spencer et al. 2010) is that both genetic and non-genetic information should be considered when defining spatial fishery management units. Genetic information often have limited power to identify population migration rates that result in spatial structure of interest to fisheries management (Waples et al. 2008, Hauser and Carvelho 2008), which may help explain why genetic structure is not observed in this example. Identifying what can be inferred from the genetic information regarding the biological nature of spatial connectivity is an important scientific task.

For the practical question of fisheries management, however, the updated data do not alter the interpretation of the non-genetic data that high rates of exploitation for western AI blackspotted rockfish have occurred in the 1990s, and abundance in this area has decreased and has not been

replenished from neighboring areas (Spencer 2013). This suggests some population structure on temporal scales of interest to fisheries management. In cases such as blackspotted rockfish that have spatially disproportionate harvest, spatial management of fishery harvest would be expected to prevent subarea depletions and maintain stock sizes that maximize yield.

Introduction

In 2013, a report on spatial analysis of survey and fishery catch data for blackspotted rockfish was presented to the BSAI Plan Team (Spencer 2013). The report noted that BSAI blackspotted rockfish show the following attributes:

1) Genetic information showing spatial structure at scales < 500 km (Spencer and Rooper 2010)
2) High catch levels in the 1990s in the WAI that have been followed with a sharp decline in WAI survey biomass estimates beginning in 2000.
3) High estimated exploitation in the WAI, where they have exceeded $U_{F40\%}$ reference exploitation rate every year from 2004-2012 except 2011.
4) An overall decline in survey biomass estimates in the WAI from 1991-2012, as estimated by a random effects time series model.
5) An increase in the proportion of survey tows which have not caught blackspotted/rougheye over all survey strata in the WAI.
6) A large percentage of the total harvest occurring in the WAI.
7) A decline in mean size in the WAI but not other BSAI subareas.

The BSAI Plan Team concurred with these conclusions, found the quality and quantity of information to be "compelling", and expressed "more concern over the local exploitation of this assemblage than other stocks that have been subjected to the stock structure template" (BSAI Plan Team minutes, September, 2013). The BSAI Plan Team reiterated its "strong concern" in its November, 2013 meeting, and noted that it anticipates a management response in 2014 if the SSC concurs with this level of concern. The BSAI Plan Team recommended that the 7 metrics shown above be updated and presented for the September meeting (BSAI Plan Team minutes, November, 2013). The SSC also "shares this concern" regarding the western Aleutian Islands portion of the stock, and agrees with the recommendation to update the seven metrics above (SSC minutes, December, 2013).

The purpose of this report is to present updates of the seven metrics above that have new information as of September, 2014. Information on blackspotted rockfish genetics was originally presented in 2010 and mentioned only in passing in 2013, and new genetic samples have been subsequently analyzed and are summarized here. The new information for metrics 2-7 is the finalized 2013 catch data and preliminary data in catches in 2014. The focus in this report is on the metrics which would be affected by updated catch data, which are the area-specific exploitation rates (attribute 3) and the spatial distribution of catch within the Aleutian Islands (attribute 6). The observations on historical catch and survey abundance (attribute 3), or attributes relying solely on survey data (4, 5, and 7) are not affected by updated catch data and are not repeated here but will be updated when the 2014 Aleutian Islands survey results become available.

Update on genetic analyses for Aleutian Islands blackspotted rockfish

Information on the genetics of blackspotted rockfish was presented to the BSAI Plan Team in 2010. The available genetic data consisted of genetic samples from 173 individuals from which 7 microsatellite loci were analyzed. The analysis was presented as one of the case studies in the 2010 report from the Stock Structure Working Group (Spencer et al. 2010), which found a significant isolation by distance (IBD) pattern, and estimated a range of lifetime dispersal distance less than 200 km. The SSWG also noted several caveats to the data: 1) the sample size is small for the large geographic scale of interest; 2) the number of loci is also small; 3) the samples may be too concentrated to prove a good estimate of the IBD relationship. However, the samples represented the best available genetic data at the time, and the finding of an IBD relation was consistent with several other rockfish species in the north Pacific. The SSWG report recommended collection of more extensive data for genetic analysis.

The genetic analysis was also presented in 2010 in the stock structure evaluation report for BSAI blackspotted rougheye (Spencer and Rooper 2010), along with additional analyses of spatial growth patterns and age composition.

Since the genetic analysis presented in 2010, blackspotted rockfish genetic samples were collected in the 2010 and 2012 Aleutian Islands trawl survey, increasing the total sample size to 942 and the number of loci analyzed to 12. A map of the sampling locations is shown in Figure 1. Additionally, the samples were obtained from many locations along the Aleutian Islands and eastern Bering Sea slope, thus addressing the concern regarding the spatial concentration of samples. With the updated dataset, a statistically significant relationship between genetic distance and geographic distance is no longer observed ($P = 0.113$).

The two studies differed not only in the number of loci analyzed and sample size, but also the location of samples. The Aleutian Islands samples in the initial study were to the east of Bowers Ridge, whereas the updated study had samples throughout the entire AI chain west to Stalemate Bank. Additionally, the EBS slope samples in the updated dataset showed a relatively large number of sampling locations along the EBS just northwest of Unimak Pass, whereas in the original study the EBS slope samples generally occurred farther to the northwest. Additional tests were conducted to determine whether the difference in results between the two studies is driven by having a larger and more representative sample size in the 2014 analysis, or rather by the inclusion of areas sampled in 2014 study that were not sampled in the 2010 study.

The original samples from the 2010 study were "rescored", in which the initial reading of the gel images were verified by running PCR amplification and reading the new gel images. The rescored data from the original samples yielded a significant IBD relationship for six of the original loci examined ($P = 0.0074$; one loci was dropped because it was viewed as relatively uninformative). Next, samples from a subset of the updated dataset in the locations sampled in the original study (n=692) yielded a marginally significant IBD relationship for six of the original loci ($P = 0.0637$) and an insignificant relationship for all 12 loci ($P = 0.1035$). These results suggest that both the change in sample size and number of loci examined contribute to the difference between the two studies, with additional loci contributing more to that difference. A final sensitivity test was performed which used the original samples but only the new loci, and yielded $P = 0.1645$. A summary of the tests are shown below:

Description	Sample size	Number of loci	P-value for IBD relationship
Original samples from 2010 study, rescored data	168	6	0.0074
Updated dataset, same loci and areas sampled in 2010 study	692	6	0.0637
Updated dataset and loci, same areas sampled in 2010 study	692	12	0.1035
Original samples from 2010 study, rescored data, only new loci	168	6	0.1645
Updated dataset and loci	942	12	0.1126

Area-specific exploitation rates

Area-specific exploitation rates are defined here as the yearly catch within a subarea divided by an estimate of the subarea biomass at the beginning of the year. Area-specific exploitation rates are generated to assess whether subarea harvest is disproportionate to biomass, which could result in reductions of subarea biomass for stocks with spatial structure. A map of the BSAI subareas is shown in Figure 2.

For each year from 2004 through 2014, the subarea biomass was obtained by partitioning the estimated total biomass (ages 3+) at the beginning of the year (obtained from 2012 BSAI blackspotted/rougheye stock assessment (Spencer and Rooper 2012), and the projection model run in 2013) into the Aleutian Islands subareas. The biomass estimates from the 2012 stock assessments and the projection model are assumed to be the best available information on the time series of total biomass, and this method can be considered a "retrospective" look at past exploitation rates. For each year, a weighted average of the subarea biomass from the three most recent surveys Aleutian Islands and eastern Bering Sea slope trawl survey (weights of 4, 6, and 9, with more recent surveys receiving higher weights) was computed, and the proportions from these averages were used to partition the biomass into subareas. Catches through August 16, 2014, were obtained from the Catch Accounting System database. To evaluate the potential impact upon the population, exploitation rates were compared to two measures of stock productivity: 1) 0.75 times the estimate rate of natural mortality (M), which is the fishing mortality F_{abc} that produces the allowable catch for Tier 5 stocks; and 2) the exploitation rate for each year that would result from applying a fishing rate of $F_{40\%}$ to the estimated beginning-year numbers, and this rate is defined as $U_{F40\%}$. The $U_{F40\%}$ rate takes into account maturity, fishing selectivity, size at age, and time-varying number at age, and thus may be seen as more appropriate for Tier 3 stocks because harvest recommendations are based upon this age-structured information. BSAI blackspotted/rougheye rockfish were managed as a Tier 5 stock prior to 2009, and as a Tier 3 stock since 2009.

Exploitation rates for the WAI blackspotted/rougheye have been at or above 0.75M for each year from 2004-2013 except 2011 and 2012, and have exceeded $U_{F40\%}$ in all years from 2004 -2013 except 2011 (Figure 3a). The preliminary 2013 exploitation rate for the WAI presented in September, 2013, was 1.51 times $U_{F40\%}$, and was based upon a catch of 61 t through July 27, 2013. The final catch of WAI blackspotted for 2013 was 84 t, which increased the 2013 WAI exploitation rate to 2.07 times $U_{F40\%}$. The preliminary exploitation rate for 2014 is 1.29 times $U_{F40\%}$. The values of $U_{F40\%}$ are similar to 0.75*M, and have decreased slightly from 2004-2011 because a large portion of the catch weight is derived from relatively young fish where the fishery selectivity (and thus fishing mortality) is relatively low; since 2011, the values of $U_{F40\%}$ have increased slightly. The exploitation rates for the other subareas do not exceed $U_{F40\%}$ with the exception of the EBS in 2010 and 2011.

Spatial distribution of harvest

The high exploitation rates in the WAI reflect that a large portion of the harvest occurs in this area, relative to a small portion of the survey biomass. From 2004-2013, 40% of the harvest in the AI management area occurred in the WAI but only 8% of the survey abundance for the AI management area. In 2013, the catch in the western, central, and eastern AI were 84 t, 62 t, and 151 t, respectively; despite the relatively large catch in the western AI (second largest since 2006), the proportion was reduced to 28% due to the large catch in the eastern AI.

Within the western AI, most of the blackspotted rockfish catch occurs in the eastern portion of the western AI between 174° E and 177° E (Figure 4). The portion of the catch between 174° E and 175° E has increased since 2008. As noted in Spencer (2013), this is an area with low trawl survey catches because the fishing grounds are not sampled in the trawl survey.

Conclusions

The main difference between this updated analysis and the analysis presented in 2013 is the reanalysis of genetic data that included a much larger sample size and additional microsatellite loci. The new analysis failed to detect a significant IBD relationship. It is useful to consider the recommendations of the SSWG report (Spencer et al. 2010), and the references it cites, on how to interpret genetic data with respect to fishery management policies.

Both genetic data and non-genetic data are useful for developing spatial fishery management strategies, as each type of information has both strengths and weaknesses. A critical attribute of a genetic definition of a population is that it is a function of the migrants (i.e., the product of effective population size –i.e., the spawning population -- and migration rate), so that marine populations with large population sizes but very small migration rates may not necessarily be considered genetically distinct from neighboring populations (Hauser and Carvalho 2008). For large populations, the migration rates at which genetic populations would be defined may be much lower that the migration rates associated with demographic independence (estimated at 10% by Hastings 1993). For large populations the difference in migration rates that either do or do not lead to demographic independence would be very difficult to identify with genetic tests (Waples et al. 2008).

In contrast, non-genetic measures may not necessarily reveal information on reproductive isolation, but could provide measures of connectivity that pertain more directly to the time-scales of interest to fisheries management. A demographic, or “ecological”, view of populations is a function of the migration rate, and reflects the relatively short-term dynamics of populations of interest to fisheries management. A genetic, or “evolutionary”, population is based on gene flow, measured by the number of migrants, over evolutionary time. Because of the relative merits of each type of information, the scientific basis for decision-making is strengthened when both are considered (Waples et al. 2008).

Levels of genetic differentiation will increase over time until migration-drift equilibrium occurs, at which point genetic differentiation reaches a stable equilibrium. Levels of genetic differentiation in blackspotted rockfish may not show a signature of isolation by distance, even though migration rates may be very low. If blackspotted rockfish occurred in a single refugium during the most recent ice advance, insufficient time may have passed to reach migration-drift equilibrium. Another possibility is that genetic structure exists due to low migration rates, but the statistical tests applied do not have sufficient power to detect the migration rate and result in a type II error (i.e., the failure to reject a false null hypotheses of no genetic structure). These possibilities will be considered in the attempt to infer the biological nature of spatial connectivity for blackspotted rockfish.

Both the evolutionary and ecological perspectives can be useful in defining what is a “stock”. However, much the discussion in recent Plan Team meetings on stock structure has not focused in defining stocks, but rather consideration of spatial management measures. Management strategy simulations for stocks with limited migration characteristic of genetic isolation by distance have recently been conducted, and indicated that partitioning catch among spatial subareas in same proportions as biomass resulted in improved yield and lower depletion than a strategy of treating all the subareas as a single management unit (Spies et al., in review).

For the practical question of identifying fisheries management strategies in this case, there is no indication that the non-genetic attributes listed above (i.e., attributes 2-7) have changed. The updated catch data indicates that the 2013 harvest of blackspotted rockfish in the western AI resulted in the highest exploitation rate since 2004. As noted by Spencer (2013), the available catch and survey data indicate that high rates of exploitation for western AI blackspotted rockfish have occurred in the 1990s, and abundance in this area has decreased and has not been replenished from neighboring areas. This suggests some population structure on the “ecological” scale that should be of interest to fisheries management. In cases such as blackspotted rockfish that have spatially disproportionate harvest, spatial management of fishery harvest would be expected to prevent subarea depletions and maintain stock sizes that maximize yield.

Finally, it is worth noting that the information that the BSAI Plan Team viewed as “compelling” and led to their conclusion of a “strong concern” in 2013 were the non-genetic attributes 2-7 above. Genetic information has not been presented to the Plan Team since 2010, and genetic attribute 1 was included in Spencer (2013) as a reminder of the previous analysis. Given that attributes 2-7 have not changed, there does not appear to be sufficient evidence to alter the conclusions the Plan Team reached in 2013.

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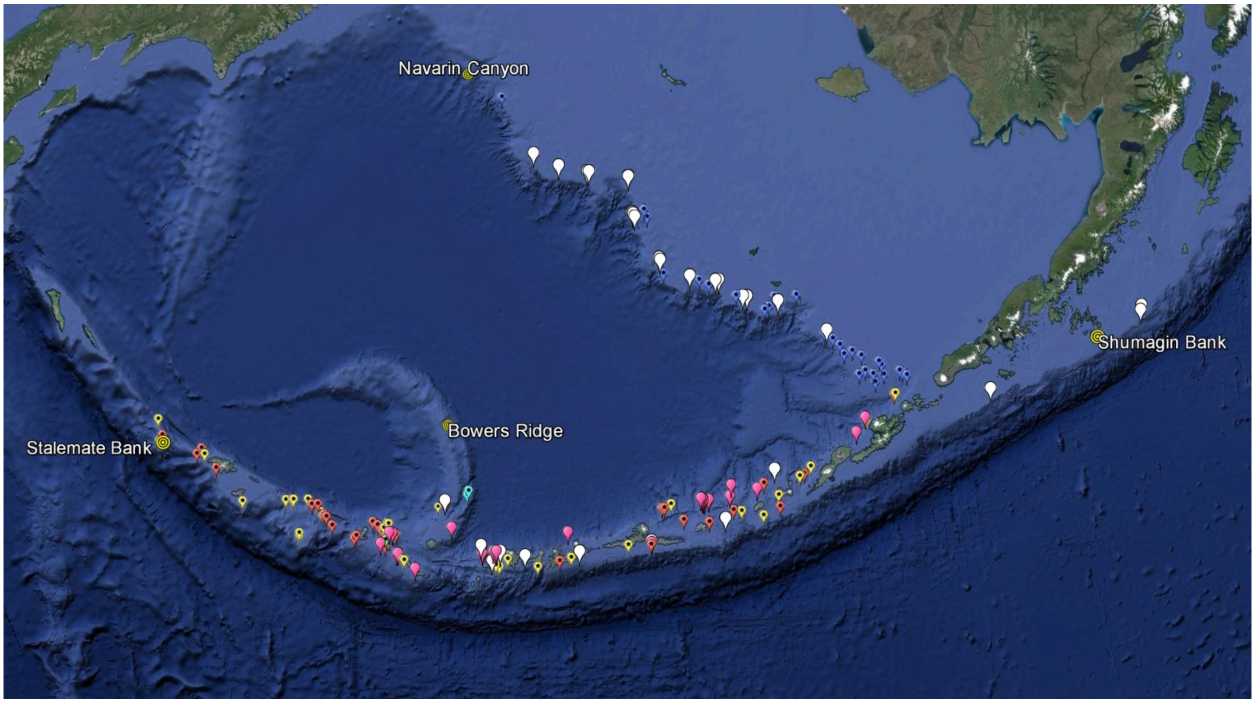

Figure 1. Map locations of genetic samples for blackspotted rockfish in the BSAI area. Symbol colors are as follows: 1) white – samples in original genetic study; 2) yellow and red – samples from two vessel in 2010 AI survey; 3) pink – samples from 2012 AI survey; 4) light blue and light green – samples from the 2010 fishery; 4) dark blue – samples from 2010 EBS slope survey.

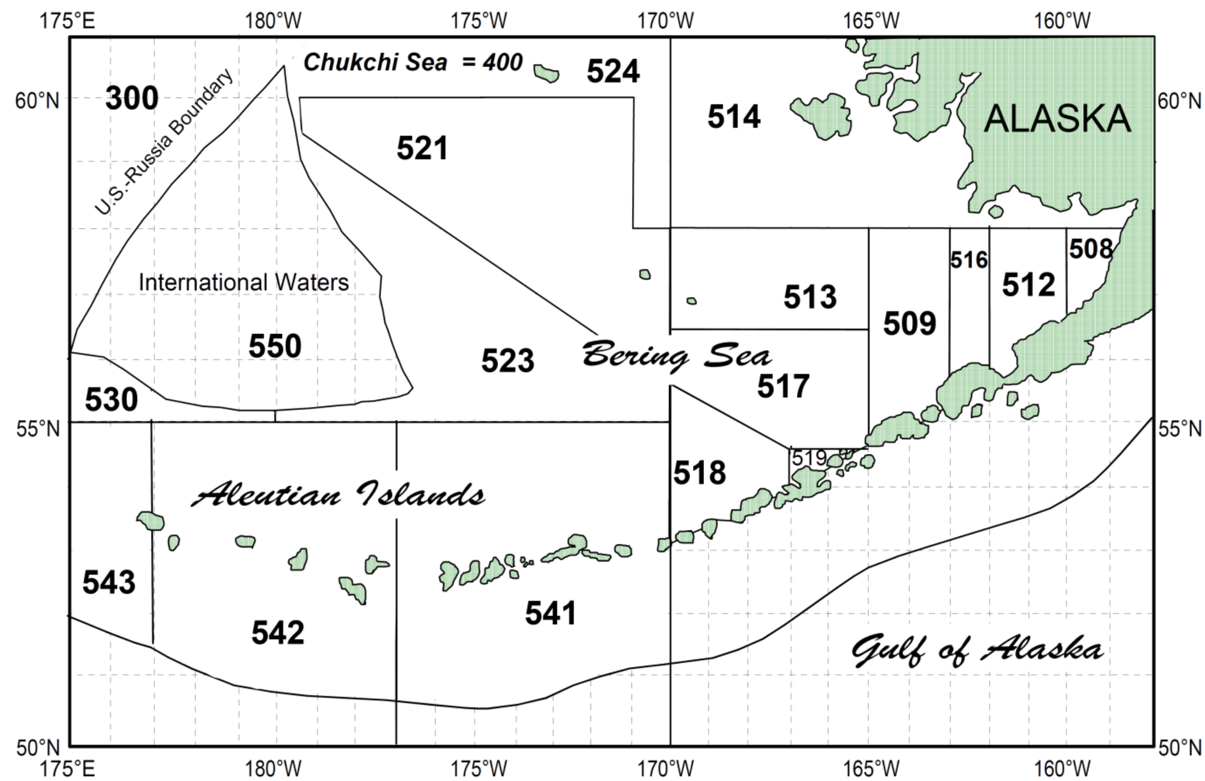

Figure 2. Map of statistical reporting zones in the BSAI management area. The western Aleutian area is zone 543 (which extends west to 170°E), the southern Bering Sea (SBS) zone comprises zones 518 and 519, and the central Aleutian Islands (CAI) and eastern Aleutian Islands (EAI) zones are 542 and 541, respectively. Figure obtained from the NOAA-Alaska Regional Management Office.

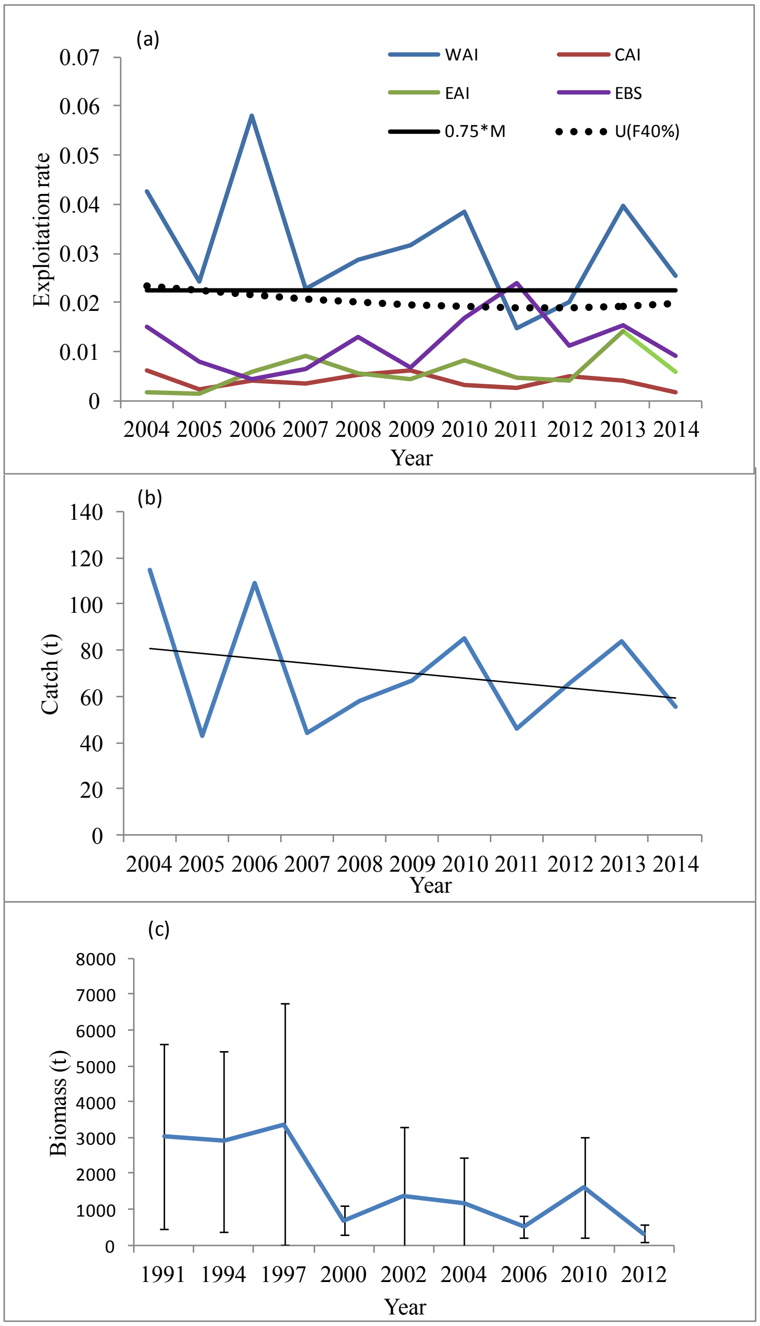

Figure 3. BSAI blackspotted/rougheye subarea exploitation rates (a), and catch (b) and trawl survey biomass estimates (c, with 95% confidence intervals) for the western Aleutian Islands. Exploitation rates and catch for 2014 are preliminary and are based on the 2012 stock assessment and projection model, and catches through August 16, 2014.

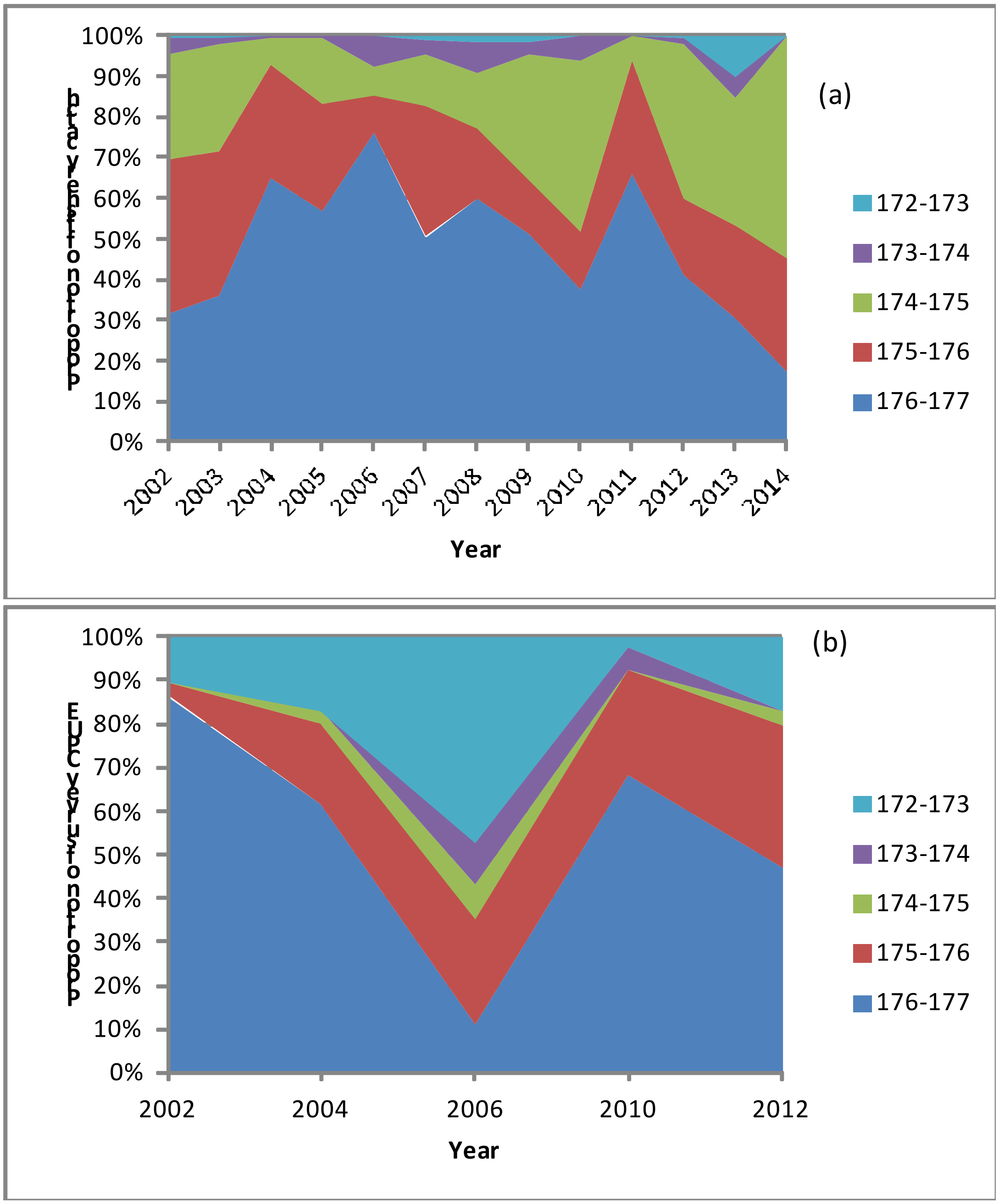

Figure 4. The proportion of fishery catch (a; from 2002-2014) and summed CPUE from AI survey tows (b; from 2002-2012) by 1° longitude bins in the WAI; the easternmost bin within the WAI occurs between 176°E and 177°E.